Coastal Mixing and Optics Moored Array

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LONG-TERM GOALS

Our long-term goal is to identify and understand the dominant vertical mixing processes influencing the evolution of the stratification over continental shelves.

OBJECTIVES

We want to understand the processes influencing the observed evolution of the stratification over the New England shelf during the Coastal Mixing and Optics program. We are particularly interested in the relative contributions of local, one-dimensional mixing processes, such as wind forced mixing, cooling, and tidal mixing versus three dimensional advective effects.

APPROACH

An array of moorings were deployed at a mid-shelf location in the Mid-Atlantic Bight in August 1996 and recovered in June 1997. The deployment spanned the destruction of the thermal stratification in fall and redevelopment of the stratification in spring. The moored array consisted of a heavily instrumented central site (70-m isobath) and three more lightly instrumented surrounding sites: about 10 km onshore (64-m isobath), 12 km offshore (86-m isobath) and 15 km alongisobath toward the east. At each site currents, temperature and conductivity measurements spanned the water column. Additionally, the central site included meteorological measurements to estimate wind stress, surface heat flux and surface buoyancy flux, wave measurements, and a fanbeam ADCP to identify Langmuir circulation.

WORK COMPLETED

A data report summarizing the moored observations has been published and distributed to CMO PIs (Galbraith et al., 1999). A manuscript describing the design of the fanbeam ADCP and its performance during the CMO experiment has been completed (Plueddemann et al., submitted). The strength and horizontal scale of Langmuir circulation were determined by detecting convergence zones in the near-surface horizontal velocity records from the ADCP. Horizontal wavenumber spectra of cross-wind velocity showed clear evidence of the growth and decay of the circulation during surface forcing events. These results were presented at the 2000 Ocean Sciences Meeting. Three manuscripts characterizing the meteorological forcing, the current variability, and the temperature/salinity variability during CMO are near completion.

RESULTS

A quantitative comparison of direct covariance momentum flux measurements to bulk aerodynamic and inertial dissipation estimates indicates that both indirect methods underestimate the flux to developing seas. The inertial-dissipation method has also been found to overestimate the momentum flux over decaying seas. The result from the inertial-dissipation method is a result of the energy exchange between the atmosphere and ocean waves. The energy flux leads to a deficit or surplus of TKE dissipation compared to traditional law-of-the-wall parameterizations, which assume a balance between production and dissipation. A modification to the traditional flux parameterization to account for wave-induced processes, developed as a part of the ONR MBL project, was applied to the inertial-dissipation estimates taken during CMO and significantly improved the agreement between the inertial-dissipation and direct covariance fluxes. This work was presented at the 2000 Ocean Sciences meeting and the NCAR/GTP workshop on Turbulence and the Air-Sea Interface.

Solar radiative heating through the water column plays a key role in determining the upper ocean thermal structure. We have been using profiling spectra radiometric measurements obtained during the CMO summer, winter and spring by H. Sosik (WHOI) to calculate short-wave transmission profiles. The resulting profiles are consistent with the Jerlov type-III coastal water type. There is a distinct difference between the summer and spring heating profiles. The summer has almost twice the short-wave transmissions at 20 m given similar surface values. In addition, there seem to be significant changes in daily transmission profiles due to changes in plankton distributions. This information will be useful in modeling and improving our quantitative understanding of changes in cold pool temperatures and thermal restratification.

The shelfbreak front separates cool, fresh shelf water from warmer, saltier slope water. The position and configuration of the shelfbreak front had a substantial impact on shelf stratification during CMO. During the winter of 1996-1997 warm, salty slope water extended onshore of the CMO moored array site in the lower water column. As a consequence the shelf remained stratified throughout the winter. Historical observations indicate the foot of the shelfbreak front was much farther onshore than normal and the resulting stratification in winter were unusual. Near-bottom temperatures were as much as 5 degrees above normal. The anomalous and persistent onshore position of the foot of the shelfbreak front was due to strong, persistent eastward (upwelling favorable) winds that caused reversals in the normally westward along-isobath mean flow.

We observed mid-depth intrusions of warm, salty slope water five times during the fall of 1996. These intrusions, often referred to as Smax intrusions, may be an important exchange mechanism between the shelf and slope. Analyses of NODC historic hydrographic observations indicate these intrusions are only observed between May and November, and are most common in August and September. The intrusions are concentrated near the shelfbreak and at the depth of the pycnocline.

Full record and seasonal mean alongshelf flows are westward between 5 and 15 cm/s with a slight maximum between 10-30 m depth. Alongshelf flow is strongest in the fall and weakest in the spring.

Mean cross-shelf flows are offshore at about 6 cm/s near the surface, decreasing to about 1 cm/s at 40 m depth and below. There is no significant seasonal variation in cross-shelf flow. At subtidal time scales (days to months) the current variability is polarized alongshelf and is correlated with the wind stress. Depth-averaged currents are most highly correlated with the wind stress oriented about 65 degrees to the left of the flow, which for the alongshelf flow corresponds roughly to the large-scale coastline orientation. Depth-averaged currents lag the wind stress by about 12 hours. Near-surface and near-bottom flows are consistent with wind and bottom stress-driven Ekman transports.

The time series of wind stress magnitude is punctuated by several intense (>0.5 Pa), episodic events often associated with passing storms. The subtidal response of the shelf currents to these strong wind stress events typically falls into one of three categories: 1. Sustained, negative (to the west) alongshelf flow; 2. Sustained, positive (to the east) alongshelf flow, against the mean flow; and 3. Rapidly fluctuating currents (period <5 days). Westward, alongshelf current events, occur during the fall and spring, follow downwelling favorable wind stress events, and accompany a decrease in stratification. The associated reduction in stratification is likely due to both vertical mixing and the offshore movement of the foot of the shelfbreak front. Current observations indicate a strongly sheared initial response to downwelling favorable wind stress, lasting the duration of the wind event, followed by a more depth-independent, westward, alongshelf flow that persists for 5 to 10 days after the wind forcing has ceased (Figure 1). The persistent westward alongshelf flow also coincides with an increase in shear near the bottom. Eastward, alongshelf current events occur during the early winter and spring, follow upwelling favorable wind stress events, and accompany an increase in stratification, due to the onshelf movement of the foot of the shelfbreak front. Strong wind stress events that occur while the foot of the front is over the shelf (identifiable at the central or offshore site) result in rapid (<5 day) variability of both the along and cross-shelf depth-averaged currents.

IMPACT/APPLICATIONS

The successful field effort has yielded the most comprehensive set of moored array data on the New England shelf for studying the processes influencing stratification over continental shelves and the associated shelf dynamics.

TRANSITIONS

None.

RELATED PROJECTS

Bottom boundary layers - We have been collaborating with Trowbridge to determine the dynamics of the bottom boundary layer and the relationship with the interior flow. We are also collaborating with Chapman (separate ONR funding) to determine whether there is a buoyancy-driven shutdown of the bottom stress as suggested in recent modeling work by Chapman and Lentz.

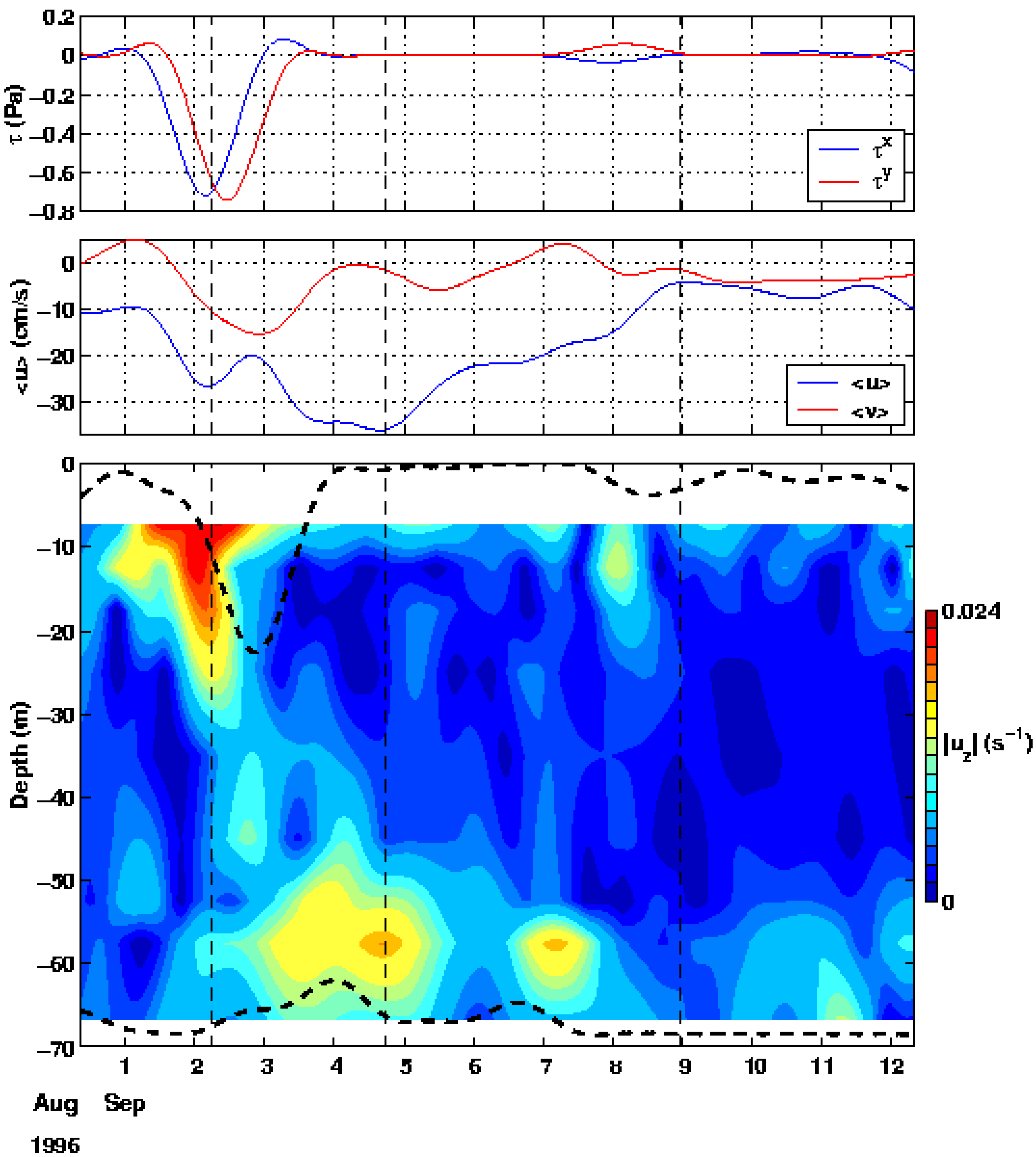

Figure 1. Subtidal, wind and currents at the central site, during the passage of hurricane Edouard, 31 Aug to 12 Sep 1996. (top) Alongcoast (blue) and crosscoast (red) wind stress (Pa), negative values correspond to downwelling-favorable and offcoast directions, respectively. (middle) Depth-averaged alongshelf (blue) and cross-shelf (red) currents (cm/s) computed from the moored current meter observations, negative values correspond to westward and offshelf direction, respectively. (bottom) Magnitude of current shear (shaded contours) with top and bottom boundary layer depths (thick dashed lines) superposed.

Optics - We have begun some preliminary collaborations with Dickey, Sosik, Boss, and others looking at the influence of strong forcing events (storms and hurricanes) on the optical properties of the water and have provided them with our data to aid in the interpretation of their measurements.

Surface Waves - Surface wave directional spectra from the CMO wave rider buoy have been compared to those derived by SAR imagery. This work was done in collaboration with Porter and Thompson (JHU). Results were presented at the 2000 Ocean Sciences meeting.

Spatial variability - We anticipate collaborating with Barth and Kosro and with Gawarkiewicz and Pickart (Primer study) to determine the influence of spatial variability in our interpretation of the moored observations.

National Weather Prediction model validation: We have been exchanging results from our NWP validation effort with Stan Benjamin, NOAA/ERL Forecast Systems Laboratory, who is developing the Rapid Update Cycle (RUC) regional weather forecasting model for NCEP, and Geoff Demigo with the ETA model run operationally at NCEP.

We continue to collaborate with the MBL PIs (Friehe, Farmer, Smith, Pinkel) in our efforts to incorporate wave-induced forcing in our modeling efforts.

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